A SYSTEMATIC COMPARATIVE ANALYSIS OF CONDITIONS ANALOGOUS TO LONG-DURATION SPACE MISSIONS

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Abstract

This paper presents interim results of a NASA/Ames Research Center study to systematically analyze conditions of isolation and confinement analogous to a proposed space station. A methodology has been developed to evaluate the relevance of candidate analogues in terms of 14 dimensions or variables. Candidate analogues include research vessels, military outposts, offshore oil platforms, long-distance yacht voyages, and remote scientific stations, to name a few. Using the comparative method and focusing on critical incidents, we explore the behavioral, psychological, and social issues affecting human adaptation and productivity in isolation and confinement. The objective of the research is to develop specific design guidelines to enhance human productivity during long-duration space missions.

INTRODUCTION

Many attempts have been made to draw behavioral inferences from situations simulating long-duration space flight. However, with the exception of Sell's (1973) attempt to develop a taxonomy of confinement and isolation, little attention has been given to the relative **appropriateness** of the analogues, or to the likely utility of the inferences. Although the comparative method has been recognized by several investigators as a potentially valuable source of data, there has been little attempt to discriminate between the relative values of the many alternative analogues. There are several problems associated with **a priori** judgments in this area. For instance, a submarine making a 90-day submerged voyage is very similar to the proposed space station in length of tour and perhaps in the hostility of the outside environment, but fundamental behavioral differences may arise as a consequence of substantially different crew sizes or other dissimilarities.

Several features distinguish our approach from other efforts to study behavior in the naturally occuring laboratories of human experience. Most notably, our approach avoids **a priori** judgments regarding the relative merit of the many conditions of isolation and confinement which may be compared to the proposed space station. Others have assumed that underwater habitats, submarines, or Antarctic research stations, to name a few, provide good examples from which to extrapolate concerning human behavior aboard a space station. We make no such assumptions. Instead we have developed a methodology to evaluate the "relative degree of relatedness" of several candidates, or alternative analogues.

In order to evaluate alternative analogues, it was necessary to first prepare a list of dimensions, or metrics, to be used to define space station conditions. In developing these definitions, we were interested in establishing the parameters or assumptions concerning expected onboard conditions; these are required to allow the comparative evaluation of alternative analogues. To satisfy this objective, we compiled the following list of dimensions.

- Size of group
- Type of tasks
- Perceived risk
- Duration of tour
- Physical isolation
- Personal motivation
- Amount of free time
- Composition of group
- Psychological isolation
- Preparedness for mission
- Physical quality of habitat
- Form of social organization
- Hostility of outside environment
- Quality of life support conditions

Certain of these dimensions are, in fact, variables rather than givens. For instance, the quality of food is considered within the dimension, "Quality of Life Support Conditions." Clearly, the quality of food that may ultimately be served aboard the proposed space station--along with many similar decisions--has certainly not yet been determined. Also, in apparent contradiction, studies such as the current effort may be used to affect determinations regarding issues such as food. It is important, however, at an early stage of this project to specify conditions as completely as possible for purposes of comparison with alternative analogues. Even the dimensions which are clearly variable require some degree of specification--if only in general terms--in order to allow a systematic comparative effort.

A research instrument was developed which included a restatement of our list of 14 dimensions and definitions. This description of a NASA space station was followed by descriptions of several alternative analogues. The summaries of the analogues used the same dimensions (e.g., size of group, type of tasks, etc.) as the space station summary to describe conditions.

The Evaluation Methodology. The space station definitions were used as target conditions against which alternative analogues could be compared. This evaluation effort involved a dimension-by-dimension comparison and the use of a seven-point scale. Data collection sheets were provided for those participating in the study to record their evaluations; each data collection sheet concerned a different descriptive dimension. Together the data collection sheets formed the matrix reproduced in Figure 1.

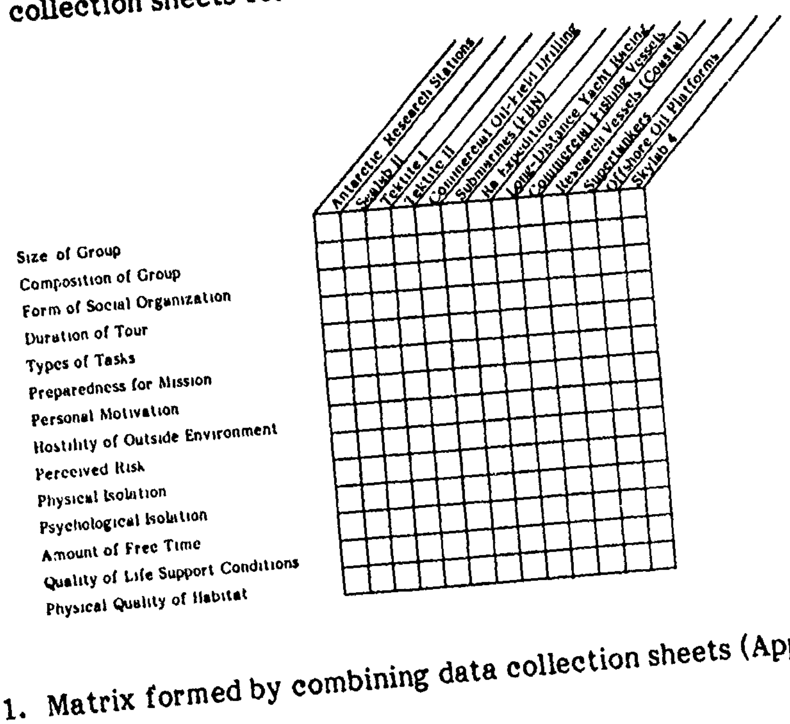

Figure 1. Matrix formed by combining data collection sheets (Appendix A).

An example of the seven-point scale is provided as Figure 2.

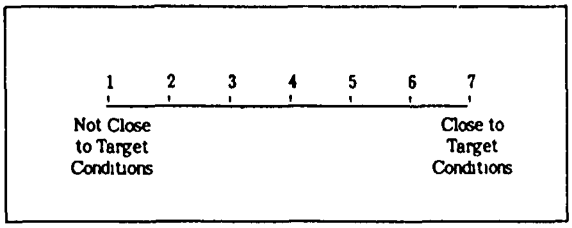

Figure 2. Seven-point scale used when evaluating "relatedness" of alternative analogues.

The procedure followed by evaluators was rather simple. For example, our space station summary assumed a group size of eight personnel. Those participating in the evaluation effort were required to select numbers on the seven-point scale to represent how closely they believed each alternative analogue corresponded to the assumed space station condition. An analogue with a group size of nine might receive a relatively high score on that dimension (corresponding closely to the crew of eight assumed for the space station). A group size of 90 would probably receive a relatively low score. Certain dimensions were more problematical than others--for instance, when comparing the physical quality of an analogue's habitat to that estimated for the proposed space station. Judgments such as these were made and recorded on the data collection sheets for each alternative analogue in terms of each of the 14 dimensions.

We recognize the difficulties inherent in quantifying subjective phenomena. We believe, however, that by providing systematic descriptions and then combining the judgments of many behavioral scientists and design engineers, we apply a more scientific method and, consequently, transcend the customary anecdotal approach to this subject. A systematic comparative effort is important because the results of the evaluation are being used to guide our efforts and determine our focus in a subsequent phase of the project.

Statistical analyses of the results of the evaluation have been conducted to identify those alternative analogues with greatest overall fidelity to expected space station conditions. The evaluation has also indicated which analogues correspond closely to expected conditions in terms of specific dimensions. Further research activity will be concentrated on those analogues indicated to be most promising by the analysis. By applying quantitative measures to comparisons of somewhat subjective conditions, we derive empirical rather than solely intuitive measures of relative analogy.

What follows is the summary of space station conditions included in the research instrument. Results of the evaluation and design guidelines were not available at the time this paper was prepared. Preliminary results were discussed, however, during the presentation of the paper.

NASA SPACE STATION (ASSUMPTIONS)

Introduction. It is likely that the construction of the space station will be an evolutionary process. In the earliest phases it may be a single cylinder attached to an enormous wing-like array of solar cells. Gradually, additional modules will be added until the space station will appear, from the flight deck of an approaching shuttle, as a grand, high-tech tinkertoy. It will not conform to our popular conceptions of what a space station should be. It will lack the lyric quality of orbiting stations depicted in novels and films; there will be no gleaming giant wheels rotating to the pleasant strains of a Strauss waltz. Rather, by the closing years of this century, the U.S. space station

will be a busy factory in the sky. It will be, first and foremost, a place of work. Onboard operations will likely involve facility and satellite maintenance, astronomy, basic science, and the commercial production of precious commodities.

Size of Group. Since the construction of a NASA space station would be an evolutionary process, we have selected the range of 6 to 12 persons for our definition. We assume a resident crew of 8 within two years of station deployment.

Composition of Group. It is expected that composition of station crews under routine conditions will be somewhat mixed in terms of sex, age, ethnicity, education, and work history.

Form of Social Organization. It is assumed that the form of social organization that has evolved within NASA for STS missions will be applied to the organization of work aboard a NASA space station. That is, a quasi-military structure with a commander, mission specialists, and payload specialists.

Duration of Tour. We anticipate tours of 60 to 90 days under operational conditions. Schedules of personnel rotation cannot be specified at this time.

Type of Tasks. Although specific information regarding the tasks involved in zero-gravity electrophoresis and materials processing are clouded by proprietary issues, we may safely assume that most onboard tasks performed by station crew will be of a vigilant and hand manipulative nature. Repair and replacement of components may be a frequent function. Extra vehicular activity (EVA) to service unmanned platforms and satellites, which is quite strenuous, will also be required.

Preparedness for Mission. It is expected that a great degree of preparation for space missions will continue to play a substantial, yet diminishing role in the future. Space station crews are likely to be at the extreme on this dimension compared to all other analogous conditions.

Personal Motivation. It is anticipated that there will be many more volunteers for positions aboard a space station than there will be positions available. It is also assumed that government pay scales are not primary motivating factors for application. For these and other reasons, it is assumed that the personal motivation of crew personnel will be other than financial.

Hostility of Outside Environment. Without mechanical means, human life cannot be supported in the environment outside the space station.

Perceived Risk. Exposure to risk will be substantial. In addition to the risk of system failures, we must consider the potential for micrometeorite collision, solar flare danger, and critical human error. The possibility exists that personnel will be required to spend a maximum of 21 days in an onboard "safe haven" awaiting rescue from a catastrophic incident.

Physical Isolation. Since the proposed NASA space station will be occupying a low earth orbit, the physical isolation from the outside world will be complete.

Psychological Isolation. It is frequently impossible to separate physical from psychological isolation. In the case of a space station, we assume that the capacity to communicate with ground control personnel and even with family members will be allowed in order to reduce the crews' feeling of psychological isolation. We anticipate that periodic, scheduled calls home will be a part of routine station operation.

Amount of Free Time. Although this dimension is of a clearly variable nature, we feel that it is necessary to estimate the amount of free time available for purposes of comparison with analogous conditions. For instance, there appears to be an abundance of free time during Antarctic winters, but very little is expected onboard a space station. Based upon the need for maintaining high levels of productivity to justify costs and on the experiences of previous space missions, we assume approximately 2½ hours per day will be available for recreational pursuits.

Quality of Life Support Systems. It is assumed that the atmospheric pressure would be maintained at 14.7 psi, the same as standard sea-level conditions; the atmosphere would likely consist of 79% nitrogen and 21% oxygen, again similar to earth conditions. EVAs and emergency operations would be conducted in compartments or suits of 8 psi. These estimates are based on current STS conditions.

It is anticipated that food onboard a NASA space station will be somewhat better (variety, texture, etc.) than is currently available on STS missions. It must also be expected that improvements will be made in the areas of hygiene. We assume, however, that full body showering will remain a luxury.

Physical Quality of Habitat. Since the building blocks that will be used to construct a NASA space station must be shuttle-compatible (i.e., they must fit in the orbiters' cargo bays), it is assumed that Spacelab-type modules will be used. For this reason, we assume that the physical qualities of the station will be similar to those aboard the orbiters and Spacelab, although modified for long-duration occupancy.

Sells, S.B. The taxonomy of man in enclosed space. In J.E. Rasmussen (editor) **Man In Isolation and Confinement,** 1973, pp. 281-303.

*NOTE: This presentation summarizes interim results of research sponsored by the Manned-Vehicle Systems Division of the NASA/Ames Research Center (NAS2-11690). Conclusions drawn from the research are the author's responsibility and do not necessarily reflect NASA opinion or policy.